Protecting Aquatic Ecosystems:

A Guide for Puget Sound Planners to Understand Watershed Processes

WASHINGTON STATE DEPARTMENT OF ECOLOGY

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Ecology Publication #05-06-027

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FINAL
December 2005, Version 1
Ecology Publication #05-06-027

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This document is available on the Department of Ecology web site at
http://www.ecy.wa.gov/biblio/0506027.html

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This work was funded in part by the U.S. Environmental Protection Agency - Aquatic Resources Unit, Wetland Program Development Grant No. CD-97080901.

Preferred citation:

Stanley, S., J. Brown, and S. Grigsby. 2005. Protecting Aquatic Ecosystems: A Guide for Puget Sound Planners to Understand Watershed Processes. Washington State Department of Ecology. Publication #05-06-027. Olympia, WA.

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Acknowledgements

The production of this document would not have been possible without the generous contribution of time and energy by numerous individuals. In particular we wish to thank several Ecology employees within the Shorelands Program: Andy McMillan, for his vision and commitment in supporting the landscape approach as an effective way to protect aquatic ecosystems in the State of Washington; Jeannie Summerhays, for her tireless efforts to help create and support the establishment of a landscape program at Ecology; Tom Hruby, for his invaluable scientific insights and careful editing of the document; Patricia Olson, for her thorough review of the methods for characterizing the processes of water flow, sediment and large woody debris; Lauren Driscoll, for her expert review and comments on early drafts and continued support and encouragement for the landscape approach; Richard Robohm, for providing timely and essential comments that greatly improved this guidance; Randy Davis for his very useful input on planning aspects of the guidance; Krystyna Kowalik for her support, knowledge and sharing of her early work on landscape analysis; and Jeanne Koenings, for her exceptional editing skills, which have been key to the transformation of this guidance into a more readable document.

Whatcom County Planning played a major role in bringing this guidance to fruition. We are indebted to Hal Hart and Jeff Chalfant for their continued support for applying a "landscape approach" to their Shoreline Plan update, and to Peter Gill for his technical input and exceptional GIS skills. Input on the landscape approach from the Whatcom County SMP Technical Advisory Committee has also assisted greatly in the evolution of this guidance.

We are extremely grateful to Margaret Clancy of Adolfson, and Chip Maney and David Sherrard of Parametrix for their patient application of the emerging methods to the Whatcom County Shoreline Plan update. Their scientific and planning expertise coupled with their application of and feedback on the methods was tremendously useful in developing both the draft and final document.

Joseph Jones and Sue Kahle (USGS) were instrumental in evaluating our early concepts for this document and helping us formulate its overall scientific framework

We also appreciate the considerable effort and time spent by peer reviewers on the draft guidance. Derek Booth's extensive review has been central to revising the scientific assumptions, rationale, and overall structure of the guidance. Tom Winter's review of the Water Flow Process (Appendix B) greatly assisted in the completion of this appendix, especially with the water flow diagrams. Many thanks to Allison Aldous, Philippe Vidon, Arthur Gold, and Noel Gurwick for helping unravel the complexities of the nitrogen and phosphorous processes. Additionally, the review of the document by Tim Beechie, Susan Bolton, Janet Carroll, Mary Kentula, Gino Lucchetti, John Owens, Doug Peters, Joanne Schuett-Hames, Peter Skidmore and Linda Storm was critical to its final development.

We are also indebted to Dick Gersib for his thorough review of this guidance and his initial work in this field during his tenure with Ecology that established the foundation for developing this guidance.

The U.S. EPA (Grant #CD-97080901-0) and Puget Sound Action Team made the funding of the work for this document possible. We wish to thank Linda Storm (U.S. EPA) and Doug Meyers (Puget Sound Action Team) for recognizing both the value of and need for taking a landscape approach to protecting our aquatic ecosystems within the state of Washington.

Executive Summary

This document provides guidance for Puget Sound planners, resource managers, and consultants on how to better protect aquatic ecosystems, such as lakes, rivers, wetlands, and estuaries, by including information about watershed processes in resource management plans and regulatory actions. (*Watershed processes* means the delivery, movement, and loss of water, sediment, nutrients, toxins, pathogens, and large woody debris.) We do this through five steps that qualitatively describe these processes. While we designed this document for use by those managing natural resources within the Puget Sound region, the steps can be applied to any region of the state.

The steps presented in this paper first identify the areas of the landscape that are important or key for maintaining watershed processes and then assess how much these areas have been altered by human activity. Finally, planners and managers can use this information to protect intact areas or restore altered areas by specifying the location, type, and density of development, as well as appropriate development standards.

The five steps use existing environmental data and land use information. We designed this method to use readily available data and to be relatively simple, rapid, and inexpensive to apply. In addition, the method is adaptable to local situations and provides products that are easy to interpret and share with others.

This method is most appropriate at the county or watershed scale. It is based on relationships at a watershed scale and so it does *not* establish a direct connection between alterations at the larger scale and ensuing impacts at the site scale. Though it does not identify site-specific restoration needs or produce mitigation plans, it is an essential step to developing these plans.

The products of this method can be used in the following ways:

- Growth Management Act
  - Support protection of critical areas (e.g., Critical Areas Ordinances) by considering key areas for watershed processes.
  - Evaluate the effect of future land use on watershed processes.
- Shoreline Management Act
  - Conduct the characterization of ecosystem-wide processes.
  - Identify areas appropriate for restoration and protection as part of the restoration plan element.
  - Identify land use designations and development standards that protect ecosystem-wide processes.
  - Meet “no net loss” requirements while allowing for mitigation flexibility.
- State Environmental Policy Act and National Environmental Policy Act
  - Consider watershed processes in the development of mitigation plans.

    - Provide information to meet the avoidance and minimization steps of “mitigation sequencing.”
- Regulatory
    - Develop a predictable permitting environment.
    - Streamline the permitting process with mitigation, credits, and fees clearly established.
- Resource planning
    - Use information on watershed processes to develop site-level restoration and protection plans.
    - Use information to develop risk-reduction strategies.

How to Use this Guidance:

- If you are a **planner**, read:
    - Sections I and II to gain an overview and basic understanding of the guidance and its potential usefulness to your needs.
- If you are a **technical specialist** determining how to apply this guidance to a particular area, focus on:
    - Section II – Overview of the steps and expected products
    - Appendices A through G – Technical rationale for identifying key areas and alterations for each process
    - Appendix H – Mapping methods

The application of this guidance requires expertise in the following areas: hydrology, geology, aquatic ecology, and geographic information systems (GIS).

I. Introduction

1.1 Importance of watershed processes

To protect and restore our lakes, rivers, wetlands, and estuaries, we must consider the watershed processes that occur outside these ecosystems (National Research Council 2001, Dale et al. 2000, Bedford and Preston 1988, Roni et al. 2002, Poiani et al. 1996, Gersib 2001, Gove et al. 2001). Our management and regulation of these aquatic ecosystems have typically concentrated on the biological, physical, and chemical character of the individual lake, wetland, stream reach or estuary, and not on the larger watershed that controls these characteristics.

> ***Watershed Processes:*** In this document, *watershed processes* refers to the dynamic physical and chemical interactions that form and maintain the landscape at the geographic scales of watersheds to basins (hundreds to thousands of square miles). These processes include the movement of water, sediment, nutrients, pathogens, toxins, and wood as they enter into, pass through, and eventually leave the watershed.

Scientific studies have shown that watershed processes interact with landscape features, climate, and each other to produce the structure and functions of aquatic ecosystems that society is interested in protecting. For example, flooding of streams can create off-channel habitat that is important for fish. Much of the research concludes that protection, management, and regulatory activities could be more successful if they incorporated an understanding of watershed processes:

- Many restoration efforts fail when they do not consider watershed processes; success would be improved if the watershed context was considered in site-level restoration (Buffington et al. 2003, National Research Council 2001, Reid 1998, Frissell and Ralph 1998, Beechie and Bolton 1999, Kauffman et al. 1997, Roni et al. 2002).
- The design of mitigation projects needs to integrate a watershed perspective (Mitsch and Wilson 1996, Preston and Bedford 1988).
- Land use planning should be developed within a framework that first focuses on maintaining or restoring watershed processes (Hidding and Teunissen 2002, Dale et al. 2000, Gove et al. 2001).

Building on these studies, the methods presented in this guidance focus on six watershed processes that play a key role in structuring and maintaining aquatic ecosystems in the Pacific Northwest (Naiman et al. 1992, Beechie and Bolton 1999, Beechie et al. 2003). These processes are the movement of

- water
- sediment
- phosphorus and toxins
- nitrogen
- pathogens, and
- large woody debris

as they enter, pass through, and eventually leave the watershed.

This document provides guidance to planners, resource managers and consultants on how to integrate information about watershed processes into their planning and decision-making. The detailed methods of this guidance are designed for use within the Puget Sound region. However, the steps presented can be applied to any region of the state.

1.2 Steps for Understanding Watershed Processes

This document is organized around five steps that can be used to understand and incorporate information about watershed processes into planning. These steps first identify areas on the landscape that are important to maintaining watershed processes and then assess the degree to which these areas have been, or are likely to be, altered by human activities.

By using these steps, resource managers will have the information necessary to protect aquatic ecosystems by developing plans that provide protection of intact areas, restore areas where processes have been altered, and reduce the potential for degradation from future development.

We developed the steps presented in this guidance so that they would:

- use readily available data
- be relatively simple, rapid, and inexpensive to apply
- be adaptable to local situations, incorporating other data easily
- produce results useful for planning
- have transparent methods that are repeatable and easily modified by the user
- provide products that are easy to interpret and to share with others

The first of the five steps is to identify the *purpose* for analyzing watershed processes and to identify technical specialists to conduct the analysis. For example, you may wish to address the problem of high nutrients in a shellfish-growing area. To address this problem, you would need input from a water quality specialist, a wetland ecologist, a hydrologist, geologist, and a data analyst/mapper.

The five steps for understanding watershed processes:

1 Identify the purpose for analyzing watershed processes
2 Map the area for analysis
3 Map key areas for watershed processes
4 Map areas where watershed processes have been altered
5 Identify potential areas for restoration and protection

Watershed*:* The drainage area contributing water, organic matter, dissolved nutrients, and sediments to a stream, lake, wetland, or other water body. This includes the area that contributes groundwater to aquatic ecosystems, which may be different from the area contributing surface water.

The second step is to map the area on which the analysis should focus. This defines the outer boundary of the analysis area and should include any upland areas that connect to aquatic ecosystems through surface water or groundwater.

Once the area of analysis has been delineated, Steps 3 and 4 characterize each process by identifying both the key areas for maintaining that process and the alterations that may have impaired the functioning of that process. In Step 5, key areas that are relatively unaltered become candidates for protection, while those that are altered are candidates for restoration.

All five steps use existing environmental data and land use information. This includes data such as surficial geology, soils, topography, land cover, land use, hydrography and wetlands.

1.3 Describing Watershed Processes

This guidance develops predictions of how water moves within a watershed based on the concept of **hydrogeologic setting** (Preston and Bedford 1988, Bedford 1996, Winter 1988). The hydrogeologic setting of an aquatic ecosystem is determined by its position in the watershed and the surrounding topography, soils, geology, and climate. Across a watershed, these characteristics govern the patterns of surface water and groundwater flow between upland and aquatic areas. The movement of water underlies most of the other geochemical and biological processes that occur in a watershed (Winter 2001, Bedford 1996, Glasoe and Christy 2004, McClain et al. 2003), and these same hydrogeologic characteristics also play a critical role in how nutrients, toxins, pathogens, large woody debris, and sediment move within the watershed. These relationships are described in detail for the Puget Sound region in Appendices A-G.

In general, human activities alter watershed processes by changing the physical characteristics of the watershed and therefore affecting the manner in which the process occurs. For example, the building of a road may interrupt the movement of water into a wetland. In this guidance the types of activities that alter each process are initially described and a set of indicators for these activities are selected. Then these indicators can be used to map the location of the activities. Details of these relationships are also described for each process in Appendices A-G.

1.4 Methods for mapping watershed processes

The final step in this guidance is the synthesis of two sets of information: first, the areas of the watershed that are key for each process and second, the location of human activities that are likely to impair each process. This synthesis is best accomplished by overlaying these two sets of information as digital maps and identifying where they overlap. Key areas that are unimpaired are potential areas for protection. Key areas that are impaired are potential areas for restoration. Both of these areas will be identified by this mapping method.

The most efficient way to accomplish this synthesis is with a GIS (geographic information system) and digital data. The methods described in the Appendices provide suggestions for using digital data to map the key areas and the alterations identified. These data are available for the whole Puget Sound region and we provide internet links to the sources of that data. We describe the kinds of information to combine (e.g., soils and geology) and how to select combinations of attributes (e.g., hydric rating and permeability) to identify the key areas within the watershed for the functioning of each process. A similar approach is used to evaluate the alterations to these key areas. The details for completing the GIS analyses are determined by technical specialists and the level of GIS expertise available. These mapping methods are described in Appendix H.

1.5 Incorporating an understanding of watershed processes into planning

Completion of this analysis will result in identification of areas where watershed processes, and therefore the aquatic ecosystems upon which they depend, can be protected or restored. This information can be used by policy and resource managers to assess the risk of future development patterns that may affect watershed processes and their associated aquatic ecosystems.

Ideally, these methods are most effective when used in the comprehensive planning process applied at the county-wide or watershed scale. This will allow communities to consider the complete set of watershed processes and their associated aquatic ecosystems. They can also evaluate how development can be sited or designed to minimize impacts to those processes and ecosystems. See Appendix J for more discussion.

There is more uncertainty associated with predictions made across a watershed than is usually found in those made for an individual site. This means that products from analyses for an entire watershed will not always be accurate for a specific site. In addition, while these methods set the watershed context for developing plans, they do not provide the specific detail necessary for site-level design. However, the information developed from this scale of analysis is essential to effective resource management and cannot be achieved by analyzing site-specific information.

Dealing With Uncertainty – Policy and resource management decisions are based on predictions of the risk of resource impairment posed by different land uses or management actions. The goal is to **minimize these risks** by basing decisions on the best information currently available.

In this regard, the best information available today suggests it is important to integrate watershed processes into the development of plans and policies to protect aquatic ecosystems. Accomplishing this can be difficult due to the uncertainties associated with extrapolating our understanding of processes occurring at the site scale to the scale of watersheds. For example:

We understand	***But our knowledge is less certain of***
The relationship between hydrogeologic conditions and water movement.	Local hydrogeologic conditions..
Which human activities are likely to alter watershed processes (i.e., additional inputs of nutrients or change to nutrient removal mechanisms).	Spatial relationships between a land use activity and a particular habitat response. Strength of the relationship between indicators of a particular activity and changes to watershed processes.

Despite this uncertainty, consideration of watershed processes is critical to effective resource management. This guidance presents a way to integrate our current understanding of watershed processes into planning. It also allows for modifications to be made as our understanding improves.

II. Details of steps for understanding watershed processes

In this section, each of the analysis steps are discussed in more detail and illustrated with an example from Drayton Harbor. This watershed is in Whatcom County near the city of Blaine and the Canadian border. Details of the methods for each watershed process are contained in Appendices B-G. The key questions to answer, the steps necessary to answer those questions, and details for answering them are outlined below:

Key Questions	**Steps**	**Details**
Why do you need to understand watershed processes? Who will assist you with the analysis? What resources already exist to help with the analysis?	Step 1: Define the purpose of the analysis	
Over what area do watershed processes operate?	Step 2: Delineate the analysis area	Include surface watershed and contributing area for groundwater
Under **natural** conditions, where are the physical characteristics important to each watershed process? Where are these different areas located?	Step 3: Map key areas for each watershed process	Describe relationship between physical characteristics of a watershed and each watershed process
Which human activities can alter each watershed process? Where do these activities occur?	Step 4: Map types of alterations to each watershed process	Describe relationship between human activities and each watershed process
Where are watershed processes still intact or minimally altered? Where have watershed processes been impaired?	Step 5: Locate potential areas for protection and restoration	Overlay Map of Alterations on Map of Key Areas for each watershed process; unaltered ► protection altered ► restoration

2.1 Analysis Steps

2.1.1 Step 1: Define the Purpose of the Analysis

Key Questions:
Why do you need to understand watershed processes?
Who will assist you with the analysis?
What resources already exist to help with the analysis?

Methods:
a. Define the purpose of the analysis: The purpose of the analysis will define the geographic area over which the analysis is conducted, the watershed processes that will be assessed, and the mechanism for integrating the results into planning efforts (Table 1). We suggest that the scope of the watershed analysis be defined in consultation with a broad range of stakeholders. Some common reasons for conducting watershed analyses and associated guidance on establishing its scope are:

i. A broad watershed planning effort designed to identify future development patterns that protect and restore aquatic ecosystems. This approach is appropriate at a county-wide scale for comprehensive and shoreline plan updates or for a watershed planning effort. Usually, all watershed processes are analyzed.

ii. Planning for restoration or conservation of a particular ecosystem or species. This application would require addressing all processes in the watershed. The products can provide a foundation for developing more detailed, site-specific restoration or management plans.

iii. An effort focused on addressing a specific environmental issue. The watershed processes to be analyzed are determined by the particular environmental problem for which solutions are sought. Products of this type of analysis could be integrated into a variety of resource management plans including those for water quality, flood improvement, and mitigation.

Table 1: Relationship between purpose, analysis area, and watershed processes requiring analysis.

Purpose	Analysis area	Watershed processes
Shoreline Management Plan Comprehensive Plan Watershed Plan	Watersheds of jurisdiction	All
Mitigation Plan Conservation Plan Restoration Plan	Watershed of ecosystem or habitat	All
Plans for addressing environmental problems, e.g., TMDLs, shellfish closures, water quality violations, etc.	Watershed affecting area of concern	Processes associated with key issue

b. Identify technical specialists: Analysis of watershed processes as described in Appendices A through H requires input from technical professionals. They should include local experts in hydrology, geology, aquatic ecosystems, and GIS analysis. This group can review the steps and methods presented in this document and make any necessary modifications based on local knowledge and information.

c. Gather existing data and resources and identify key environmental issues: Once the scope of the analysis has been identified, relevant existing reports, studies, and inventories should be collected for integration into the analysis (Table 2). These resources can be used to identify key environmental issues for which solutions are being developed. Additionally, based on the GIS methods listed in Appendix H, you should evaluate the usefulness of current digital data.

Table 2: Selected sources of existing information and data

Type of information	Studies/plans	Website
TMDL studies and listings	Water bodies exceeding water quality standards (303d list)	http://www.ecy.wa.gov/programs/wq/303d/2002/2004_documents/list_by_category-cat5.html
	TMDL clean up plans	http://www.ecy.wa.gov/programs/wq/tmdl/watershed/index.html
Habitat and water quality monitoring/ assessment reports	Puget Sound Action Team list of reports on marine environments	http://www.psat.wa.gov/Publications/Pub_Master.htm
Watershed planning reports	Ecology list of watershed planning reports	http://www.ecy.wa.gov/watershed/index.html
Studies/environmental reports	Limiting Factors Reports	http://salmon.scc.wa.gov
	Site-specific studies	Literature data bases, tribal websites, agency websites

The amount of information available for any particular location varies considerably across the state. Some areas have many local studies while others have very few. It is important to evaluate the information that exists to decide how it can contribute to this analysis. What was the purpose of the study? How are the results useful?

Products:

- Geographic area and watershed processes to be analyzed
- Technical specialists identified to complete the analysis
- Compilation of existing reports, data, and resources

Example:

Below we present an example of this step for Drayton Harbor in Whatcom County.

a. Scope of the analysis: The Washington State Department of Health closed Drayton Harbor shellfish beds in the late 1990s due to fecal coliform contamination. In addition, the Puget Sound Action Team reported problems with algal blooms, indicating high nutrient levels in Drayton Harbor. As a result, this watershed analysis is to address the environmental problems of high levels of nutrients and high fecal coliform concentrations in Drayton Harbor.

The geographic area for analysis is the two watersheds that contribute to the Harbor – California and Dakota creeks. The analysis of watershed processes will focus on the delivery, movement, and loss of **water, nitrogen, phosphorus, and pathogens**. The products will provide a watershed context for prioritizing activities, such as restoration or protection, to address the fecal coliform and nutrient contamination of Drayton Harbor.

b. Identify technical specialists: To conduct these analyses, we include a GIS analyst, a wetlands ecologist, and a hydrogeologist familiar with the area.

c. Gather existing resources and data: We assess the numerous planning and scientific studies conducted in this area before we begin the watershed analysis. Extensive information on environmental conditions in Drayton Harbor can be found in a host of studies. The 303D listings on the Department of Ecology website indicate that Drayton Harbor and Dakota Creek exceed fecal coliform standards. In addition, review of the Puget Sound Action Team publication site identifies several useful studies. One document, "Blooms of Ulvoids in Puget Sound" (Frankenstein 2000), reports that Drayton Harbor had algal blooms, which are an indicator of high nutrient levels. Fecal coliform studies produced by the Northwest Indian College and Whatcom County Health Department are also consulted. In addition, we acquire all available GIS data needed for the analysis from existing state and local data sources for geology, topography, soils, precipitation, and land use**.**

2.1.2 Step 2: Delineate the analysis area

Key Question*:*
Over what area do watershed processes operate?

Methods*:* This step defines the scale at which you will need to analyze watershed processes. The product, Map 1, identifies the area that contributes surface and ground water to the aquatic ecosystems. The processes associated with the movement of sediments, nutrients, pathogens, toxins, and large woody debris are assumed to operate within this same scale.

Even though groundwater and surface water are tightly linked and are equally important components of water movement, surface watersheds do not always correspond with the recharge area for ground water (Winter et al. 1998). Therefore, the area of analysis is initially delineated using surface water drainages and then is refined by determining the area that contributes to groundwater recharge.

In many locales, watershed boundaries have already been developed and used extensively in other projects. To maintain consistency, these boundaries should be adopted for this work to the extent possible. In some cases, you may need to alter these existing boundaries as, for instance, surface water drainages have been altered from their natural state or the drainages of interest are smaller than those previously delineated. You can then use elevation patterns, visible from either Digital Elevation Models (DEM) or topographic maps, to delineate watershed boundaries.

You can determine the approximate contributing area for groundwater by examining the surficial geology and topography. In glaciated landscapes, the surficial deposits are tied to and govern soil permeability and hydraulic conductivity (Vaccaro et al. 1998) (Appendix B). The grain size of a deposit is a good indicator of its conductivity except in highly consolidated formations such as till (Vaccaro et al. 1998). In general, if a deposit that is highly permeable extends beyond a surface water boundary, then the watershed boundary (or contributing area) may need to be adjusted. A local hydrologist or geologist should be consulted when developing these boundaries.

Products: Map 1– Map of the analysis area

Example:

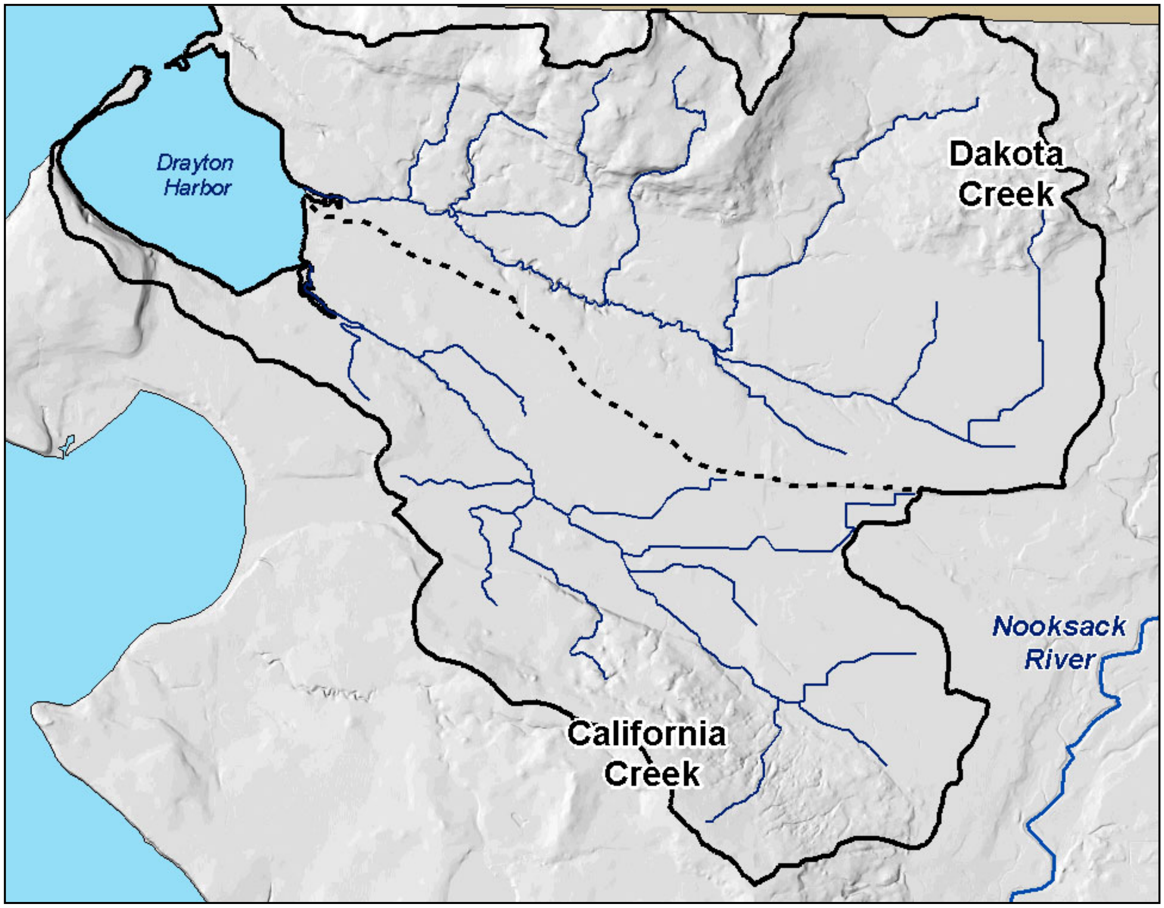

Figure II-1. Example of Analysis Area for the Drayton Harbor Watershed (Map 1). The solid black line shows the area contributing to Drayton Harbor. The major streams are the thinner, solid blue lines. Though the dashed line is the surface water boundary between the California Creek and Dakota Creek drainages, there is groundwater movement beneath this boundary.

2.1.3 Step 3: Map 'key areas' that are important for each watershed process

> ***Key Question:***
> Under **natural** conditions, where are the areas with physical characteristics that are important to each watershed process?
> Where are these different areas located?

Methods: This step focuses on describing the physical characteristics of the watershed, or the hydrogeologic setting, that governs the performance of each watershed process. Our current understanding of these relationships is described for each process in the key areas section of Appendices B-G. Those areas with characteristics that support each process are identified as "key areas" in the rest of this document. As the final part of this step, the places in the watershed with these physical characteristics are mapped (Map 3).

GIS analyses: Using GIS, you can map the key areas for each watershed process identified in the Appendices. Appendix H provides suggestions for using regionally available datasets to map these key areas; however, if local data exist, they may be preferable.

Products: Key Areas Map (Map 3): A separate map is produced for each process. On each map, key areas for each component of the process (i.e., delivery, movement, and loss) are mapped in different colors.

Example: Although we identified three "key" watershed processes in Step 1 for Drayton Harbor, the examples from here forward are only for the movement of **water**. In fact, to better illustrate the steps, we have focused only on the subsurface movement of water, which includes groundwater recharge.

Using Appendix B as a guide (Table B-1), the **permeability** of surficial geologic deposits in a watershed governs the subsurface movement of water. Key areas for both subsurface flow and recharge of groundwater are found where these deposits are permeable. As a result, the map of key areas for these components of water movement highlights the places where the underlying geologic deposits in the watershed have moderate to high permeability (Figure II-2).

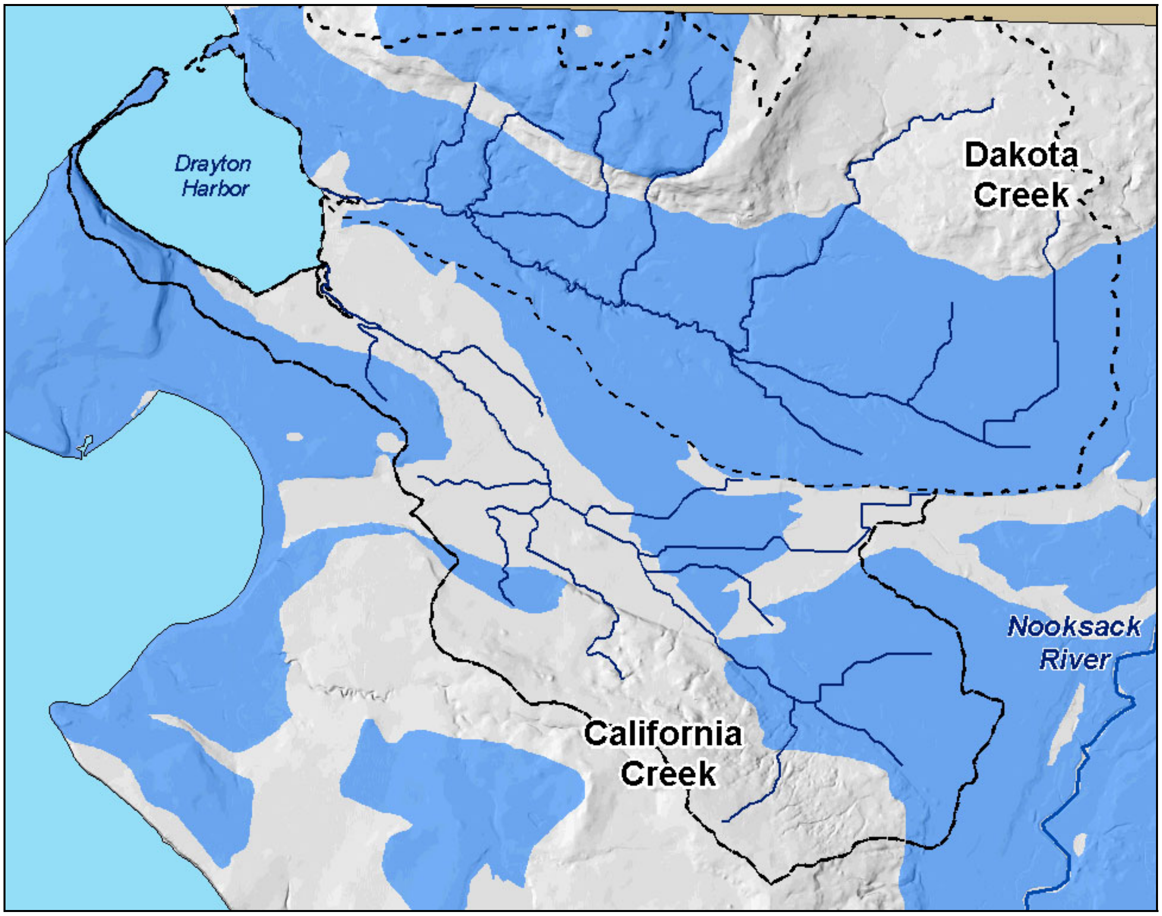

Figure II-2. Example of Map of Key Areas (Map 3) for the Drayton Harbor watershed. Blue areas show underlying geologic deposits that are more permeable.

2.1.4 Step 4: Map types of alterations to each watershed process

Key Questions*:*
Which human activities can alter each watershed process?
What activities occur?

Methods*:* In this step we focus on identifying those activities that are likely to alter each watershed process. Many human activities affect the physical characteristics of a watershed, thus affecting watershed processes. For example, construction of impervious surfaces, such as roads or buildings, can prevent the downward movement of water into surficial deposits. This reduces the amount of groundwater recharge and increases the amount of surface runoff. Our current understanding of these relationships is described in illustrations for each process in the alterations sections of Appendices B-G.

The goal of this step is to map the locations of the human activities that impair watershed processes. However, many of these activities are not easy to map, such as nutrient inputs. As a result, we use indicators that strongly correspond to these activities and are easier to map (agriculture land cover). These indicators are summarized in the alterations sections of Appendices B-G.

GIS analyses*:* You can map indicators of human activities that impair each watershed process using GIS. These indicators are identified in the illustrations for each process in the Appendices. Appendix H provides suggestions for using regionally available datasets to map these altered areas. However, if local data exist, they may be preferable.

Products*:* Alteration Map (Map 4). A separate alteration map is produced for each watershed process.

Example*:* Again using Appendix B as a guide (Table B-3), we identify the type of human activity that degrades the subsurface flow and recharge of groundwater. In this case, it is the conversion of forest to either impervious surfaces or non-forested vegetation. Impervious surfaces clearly prevent percolation of water into the ground, thus reducing groundwater recharge. Research has also found that removal of forests is associated with a reduction in the downward movement of water, thus shifting subsurface flow to surface water runoff.

For Drayton Harbor, we use urban land cover as an indicator of impervious surfaces, and agricultural and urban land cover as an indicator for removal of forested vegetation. Forested land is used as an indicator of remaining forested vegetation. We map each of these land covers in a different color to produce an Alteration Map for these components of water movement (Figure II-3).

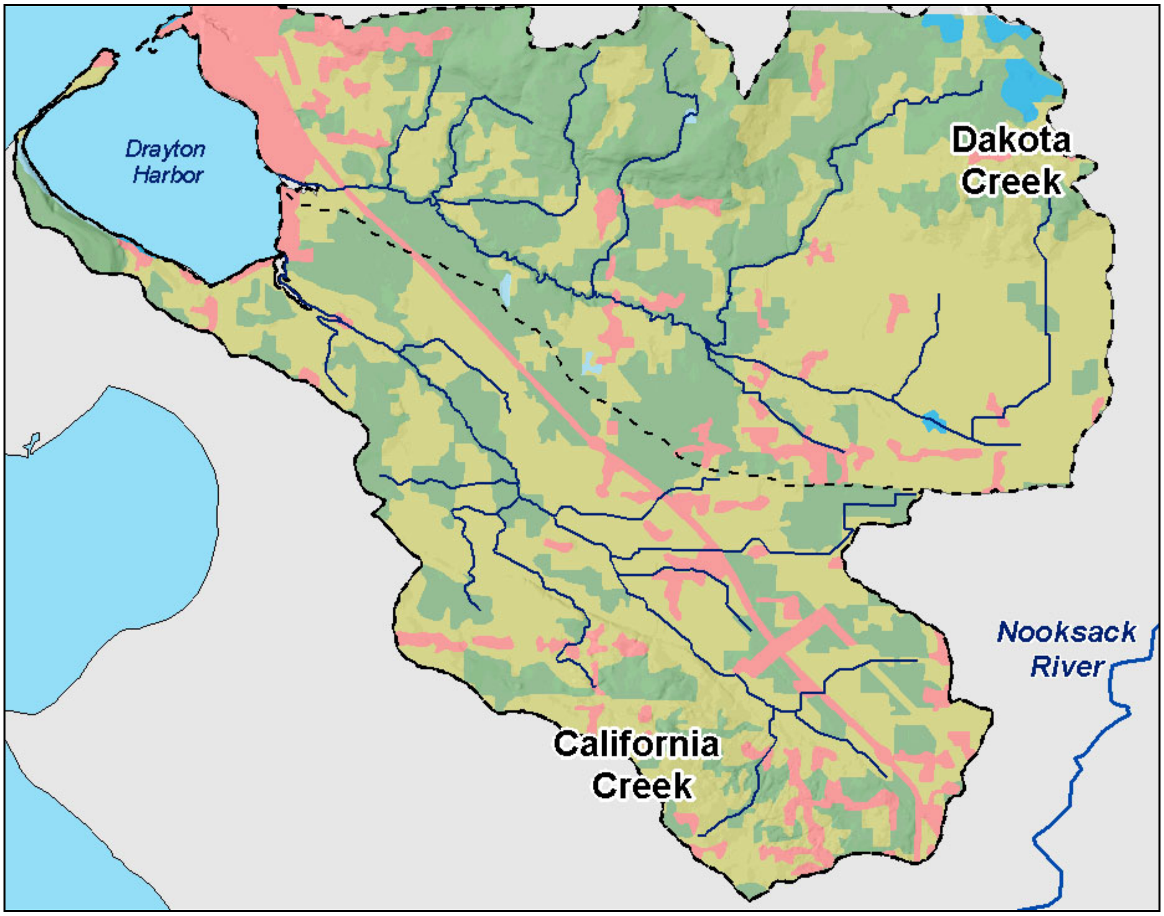

Figure II-3: Example of Alterations Map (Map 4) for Drayton Harbor. Urban land cover is **pink**, agricultural land cover is **tan,** and forested land cover is **green**. Larger wetlands and water bodies are **blue**.

2.1.5 Step 5: Locate areas for protection and restoration

> ***Key Questions****:*
> Where are watershed processes still intact or minimally altered?
> Where have watershed processes been impaired?

Methods: Upon completion of steps 3 and 4, we have produced two sets of maps for each watershed process. The first map locates the key areas for each watershed process, while the second locates alterations that degrade these processes. Overlaying the Alterations Map (Map 4) on the Key Areas Map (Map 3) will highlight where each process has been impaired and where each has been minimally altered.

Key areas that have not been altered may be candidates for protection, thus ensuring that the associated watershed process will remain intact. Key areas that have been impaired may become candidates for restoration, thus increasing the likelihood that associated watershed processes will be restored. The protection and restoration of watershed processes is a critical step towards protecting the aquatic ecosystems in a watershed.

***Protection*:** Any activity that ensures that the watershed process supported by a key area is relatively unimpaired. This can encompass traditional efforts of protecting land from human activities (e.g., open space, conservation easements), but it can also extend to designing development in a way that allows the watershed process to continue with minimal impairment. For instance, an area important for recharge could be set aside from any development, or new development could be sited and designed to ensure recharge of the additional surface runoff generated by the development.

Restoration: Any activity that ensures that the watershed process associated with a key area is reinstated. This can involve restoring the natural condition of the site, but it can also include activities that restore the capacity of the important area to support the process. For instance, an area important for recharge that is covered with impervious surfaces could be modified to accommodate recharge or it could be restored to natural conditions.

The specific design of any of these activities requires further site-level analysis.

GIS analysis*:* Overlay of the Alterations Map (Map 4) onto the Key Areas Map (Map 3) for each process

Product*:* Map 5 - Overlay of Map 4 onto Map 3
Location of Potential Areas for Restoration and Protection

Example*:*
As this is a data analysis and synthesis step, mapping should be done in a way that best facilitates interpretation of the data and integration into planning. There are many different ways that this can be accomplished including overlaying the Alterations Map for subsurface flow and recharge over the Key Areas Map. For more mapping ideas, see the mapping section of Appendix H.

In this example, we found it useful to present the alterations data in a different format from that shown in Step 4 (Figure II-4). Rather than using the actual locations of each land cover, we summarize the percentage of a sub-basin in each of the three land covers (urban, agriculture, and forested). This information is then displayed in a pie chart for the sub-basin. Seven sub-basins are shown to illustrate the variation within the watershed and to simplify the display.

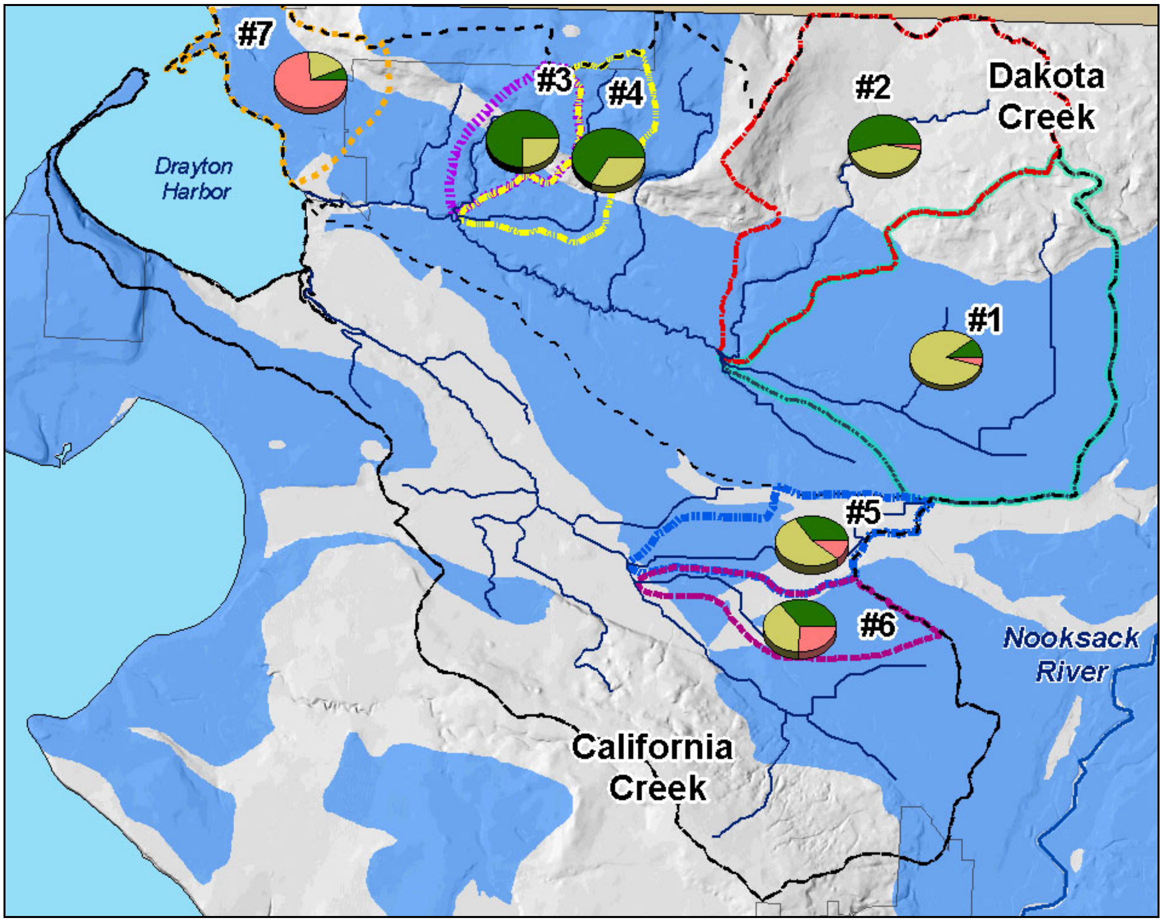

Figure II-4: Example of Map 5 using land cover alteration data. This map shows the key areas for the recharge component of the water movement process and the degree of alteration**.** The pie charts show the land cover composition of seven selected sub-basins in the Drayton Harbor watershed. The proportion of the sub-basin that is forested is green, the proportion that is non-forested is tan, and the proportion that is impervious is pink. In addition, the key areas for water movement, high to moderate permeability, are in blue.

The information on each sub-basin presented in Figure II-4 can be used to identify priorities for each sub-basin. A planner using this approach would then be able to identify which areas to prioritize for restoration of watershed processes, for restoration of site level functions, for enhancement of selected attributes, or for protection of both functions and watershed processes. In Figure II-5 we provide an example of one approach for identifying priorities for sub-basins. This approach was developed for nearshore environments (Shreffler and Thom 1993), but adapted here for freshwater ecosystems.

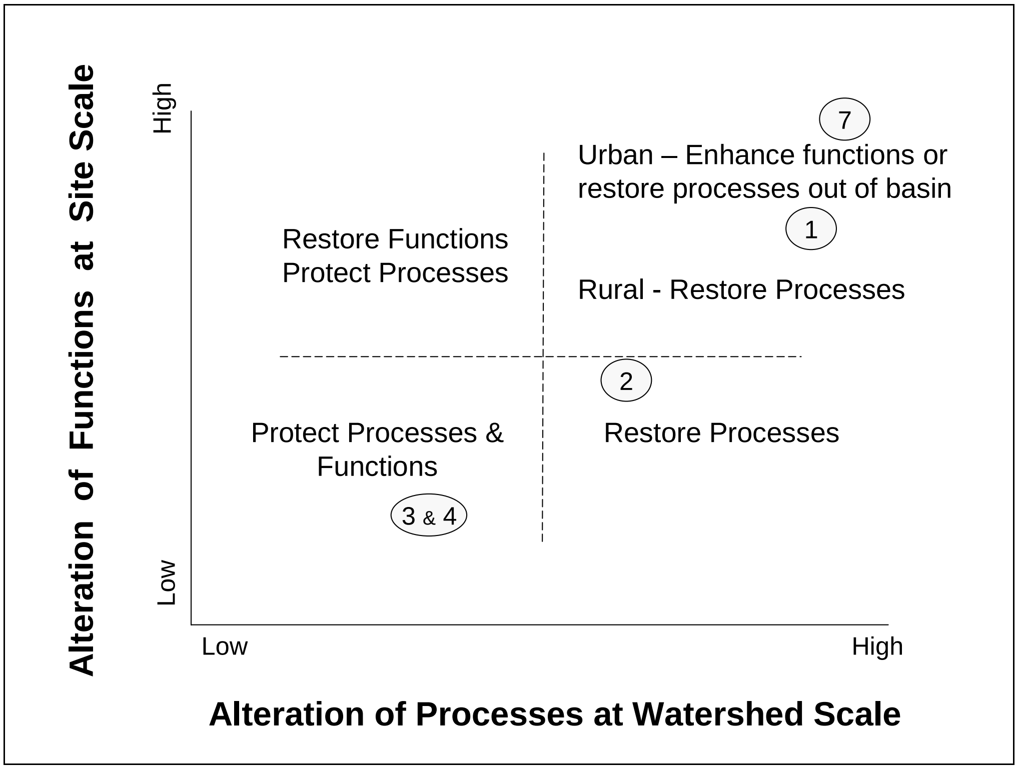

Figure II-5: Example of prioritizing restoration and protection efforts based on degree to which the watershed processes and site functions have been altered. . Numbers in circles refer to sub-basins in Figure II-4. It is assumed that alteration of processes are not permanent (i.e., paving, buildings) except for urban sub-basins (e.g., #7). Adapted from Figure 5-2 in Shreffler and Thom (1993) and Figure 9 in Booth et al. (2004).

- *What this overlay map tells us:* Sub-basins 3 and 4 have the least amount of impervious cover and a large percentage still in forest. This indicates the subsurface flow and recharge components of water movement are least altered in those sub-basins and that most of the aquatic habitat and their functions would be relatively intact. Sub-basin 7 shows the reverse with a large percentage in impervious surface. It is likely that the most-altered components of water movement in this sub-basin are subsurface flow and recharge, as well as the functions of aquatic habitat.

- *How this can integrate into plans to restore aquatic ecosystems:* This information could guide the overall objectives of restoration projects in these sub-basins by ensuring that focus is placed where it is needed most to restore water processes. Furthermore, it can guide on-the-ground activities by suggesting that they focus on restoring subsurface flow and groundwater recharge in areas where land use changes have altered these components of water movement.

  For example, restoration of processes in sub-basin 1 is appropriate given the considerable degree of process alteration (agricultural activity) but a low level of permanent alteration (impervious cover). Because sub-basin 1 also covers the largest area of permeable deposits for Dakota Creek and is located in the upper portion of the basin, restoration measures could have a significant effect on restoring water flow processes. In comparison, restoration in sub-basin 6 may not be appropriate given the higher level of impervious cover that may have permanently and significantly altered watershed processes and functions.

Compensation for future development impacts to aquatic ecosystems in sub-basins with a very high level of alteration may be more appropriately directed to less altered sub-basins. For example, compensation for impacts to wetlands in sub-basin 7 may provide more overall environmental benefit if undertaken in a less altered area, such as sub-basins 1, 2, 3, or 4.

- *How this can integrate into plans to protect aquatic ecosystems:* The information can guide future efforts to minimize alteration to water movement in sub-basins where land cover change has so far had minimal effects. For instance, planning in sub-basins 3 and 4 should focus on protecting subsurface flow and recharge. In addition, future development in sub-basins 3 and 4 could be restricted or designed to reduce impairment to both subsurface flow and groundwater recharge by clustering development and incorporating infiltration measures (Department of Ecology 2005).

2.2 Incorporation of results into existing planning efforts

The steps outlined in this guidance will produce information that is most useful when applied within a planning framework for either a governmental or a private entity responsible for land management (see Appendix J for more detail). It should be used to guide the development of a management plan so that it provides for the long-term protection and maintenance of aquatic ecosystems. Examples of possible applications for governmental entities include a comprehensive plan, shoreline management plan, watershed plan, or development plan. For private entities, this could include habitat management and conservation plans.

Now that you have a basic understanding of the five-step approach of this analysis, you can begin to review methods presented in the appendices. The details provided in the appendices are designed to help you understand how to produce the maps discussed in this section so that they can be incorporated into your planning efforts.

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